AL/HR-TR-1993-0173

ARMSTRONG LABORATORY

MODELING THE REQUIREMENTS PROCESS

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DECEMBER 1993

FINAL TECHNICAL REPORT FOR PERIOD JANUARY 1991 - APRIL 1992

Approved for public release; distribution is unlimited

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1993	Final - January 1991 to April 1992

4. TITLE AND SUBTITLE
Modeling the Requirements Process

5. FUNDING NUMBERS
C - F33615-88-C-0004
PE - 62205F
PR - 1710
TA - 00
WU - 40

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Armstrong Laboratory
Human Resources Directorate
Logistics Research Division
2698 G Street
Wright-Patterson AFB, OH 45433-7604

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AL/HR-TR-1993-0173

11. SUPPLEMENTARY NOTES
Armstrong Laboratory Technical Monitor: Janet L. Peasant, AL/HRGA, (513) 255-8502

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report describes the environment associated with the identification, validation, tracking, and management of operational and support requirements for Acquisition Category I weapon systems within the Air Force, including the processes and sub processes, products and/or documentation required and produced, and the organizations involved. It also identifies and describes opportunities for the fabrication and use of a decision support system to improve various sub processes.

14. SUBJECT TERMS
decision support
requirements software
weapon systems

15. NUMBER OF PAGES
45

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std Z39-18
298-102

CONTENTS

		Page
	PREFACE	vi
	SUMMARY	1
I.	INTRODUCTION	2
	Purpose	2
	Report Structure	2
II.	BACKGROUND	3
	Defense Acquisition Reform	3
	Total Quality Management and Concurrent Engineering	4
	Summary of Changes to the Requirements Process	5
	Air Force Restructuring	9
	Impact of Restructuring on Project Analysis	10
	Decision Support System for Requirements	10
III.	TASK CHRONOLOGY	11
	Phase I: Preparation	11
	Detailed Research Plan	12
	Literature Search	13
	IDEF Instruction	14
	Phase II: Modeling the "Schoolhouse" Requirements Process	15
	Phase III: Modeling the "Practice " Requirements Process	16
	Phase IV: Model/Process Analysis, Decision Support System Recommendations and Final Report	16
IV.	MODELING METHODS	16
	IDEF Methodology	16
	The Integrated Computer-Aided Manufacturing Definition Experience	18
V.	ANALYSIS OF MODELS	19
	Assumptions Underlying the Models	19
	Scope of the Modeling Effort	20
	Inherent Limitations of the Modeling Effort	21
	Differences Between the Schoolhouse and Real-World Process	21

CONTENTS (Cont.)

Page

Opportunities for Decision Support System Implementatio 22
Decision Support System Tasks 22
Mission Area Assessment and Mission Need Analysis 23
Design Specifications 24
Integration/Project Management 25
Training . . . . .
26
Evolutionary Requirements Definition 27
Strategy-to-Task Analysis 28
Emphasis on Early Acquisition Activities 29
VI. CONCLUSIONS 30
Limitations of the Study 30
General Findings 31
Future Directions for Similar Work 33
REFERENCES 34
ACRONYMS 35

TABLES

Table		Page
1	Comparison of Program Milestone and Phases	6
2	Comparison of Air Force and Milestone Review Documents (ACAT I Programs.	7

PREFACE

This research effort described by this paper was performed under Armstrong Laboratory Logistics Research Division Work Unit 1710-00-40, Task 32, Modeling the Requirements Process, through a contract (F33615-88-C-0004) to Systems Exploration, Inc. Mr. Art Schwaninger was the principal investigator. He was assisted by Mr. Mark Miller, Ms. Patti Jo Vore, and Ms. Colleen Gumienny.

This paper is a product of a study effort aimed at gaining an in-depth understanding of the Air Force major weapon system requirements process as it is described in the various governing directives, and an understanding of how those directives are interpreted and practiced in the field. The study examined the role of computer support for the process; this paper describes the development of a graphic description of the requirements process. Integrated Computer-Aided Manufacturing Definition methods were the media for this description.

The authors wish to thank Captain Raymond R. Hill for his assistance and guidance, especially in the area of study design, and Mr. Brett Andrews of the Air Force Institute of Technology School of Systems and Logistics for his assistance in the development of the structured interviews with subject matter experts. We also wish to thank the many subject matter experts who provided insight into both the interpretation of directives and the practice of managing evolving requirements.

SUMMARY

This paper describes the environment associated with the identification, validation, tracking, and management of operational and support requirements for Acquisition Category (ACAT) I weapon systems within the Air Force, including the processes and subprocesses, products and/or documentation required and produced, and the organizations involved. It also identifies and describes opportunities for the fabrication and use of a decision support system (DSS) to improve various subprocesses.

The description and analysis of the requirements environment was facilitated by the construction of Integrated Computer-Aided Manufacturing Definition (IDEF) model descriptions of the requirements process. (Integrated Computer-Aided Manufacturing Definition, Activity Modeling (IDEF0) and Integrated Computer-Aided Manufacturing Definition, Process Modeling (IDEF3) were the specific methods used.) The requirements process as defined for this paper, extends from the need determination or pre-Milestone 0 phase through the Milestone III decision to enter into the production and deployment of a weapon system.

The source of the data used to construct the models came from three primary sources: (a) the government directives: Department of Defense Directive (DoDD) 5000.1, Department of Defense Instruction (DoDI) 5000.2, and Department of Defense Manual (DoDM) 5000.2-M, and Air Force Regulation (AFR) 57-1; (b) interviews with subject matter experts from the operating commands (Headquarters (HQ), Tactical Air Command (TAC), and Strategic Air Command (SAC)), implementing command (HQ Air Force Systems Command (AFSC) Aeronautic Systems Division (ASD)), supporting command (HQ Air Force Logistics Command (AFLC), and Oklahoma City Air Logistics Center), Air Staff (primarily the Policy and Joint Requirements Division (AF/XORJ) and the office of the Deputy Assistant Secretary (Management Policy and Program Integration) (SAF/AQX)), and faculty members of the Air Force Institute of Technology (AFIT) School of Systems and Logistics; and (c) an extensive library of current literature provided by Armstrong Laboratory.

The research performed under this contract indicates that a DSS would greatly enhance the Mission Area Assessment (MAA) and Mission Need Analysis (MNA) segments of the need determination process. Furthermore, a DSS would emphasize and encourage the employment of concurrent engineering (CE) principles throughout the acquisition process. It would be of considerable value in integrating the vast amounts of similar data in the myriad documents

involved in an ACAT I acquisition. Finally, the DSS can be readily adapted to fulfill the pressing need for training of personnel working within the requirements process

Based on the research conducted under this contract, it is recommended that a DSS be constructed for ACAT III and lesser acquisitions, and that research begin to identify existing software packages that could be readily adapted to such a DSS. A DSS that could significantly enhance the requirements process is well within current technology

I. INTRODUCTION

Purpose

The purpose of this effort was to research the processes by which Air Force weapon system requirements are generated, identified, validated, traded, documented, tracked, and managed within the larger acquisition process. The results of this research were then used to identify those activities or subprocesses that could be improved through the application of computerized decision support technology.

The scope of this task extends from the Determination of Mission Need (the Pre-Milestone 0 Phase) through the Milestone III Production Approval decision. The scope includes only major acquisitions that are designated ACAT I.

Modeling provided a structured means to gain an in-depth understanding of the environment of Air Force requirements and acquisition personnel, and to describe the functions and processes of system acquisition as they relate to mission and system requirements.

Two sets of models were constructed. One set describes the processes prescribed by Department of Defense (DoD) directives; the other describes the practical interpretation and application of these directives by field personnel. After the models had been developed and refined, they served as the foundation for an analysis of decision support technology opportunities.

Report Structure

This report summarizes the technical work accomplished and the information gained by modeling the requirements process. The report contains a discussion of the background factors

which led to the need for this research, including a summary of some of the major changes to the requirements process, followed by a chronology of the task. This chronology includes a complete discussion of the rationale, methodologies employed, and basic assumptions of the research approach. The report then focuses on the IDEF0/IDEF3 modeling task, discusses relevant acquisition topics, and presents conclusions and recommendations for future studies.

II. BACKGROUND

Defense Acquisition Reform

Defense spending and acquisition practices generated considerable public concern in the mid-1980s. During this period, the media was fraught with stories of overpriced spare parts, test deficiencies, and cost and schedule overruns. Consequently, the President appointed a Blue Ribbon Commission on Defense Management (often referred to as the Packard Commission) to evaluate the defense acquisition system and determine how it could be improved. The Commission sought changes that would lower the cost of military equipment without compromising performance.

The Commission analyzed reports of gross inefficiencies and determined that the "cure" would require more than bandages applied to isolated surface problems. After concluding its efforts, the Commission produced a host of recommendations designed to address significant, structurally embedded problems, such as the length of the acquisition cycle.

In addition to the Packard Commission, other critics with both rank and experience in the process have written extensively on the ills of the system as practiced before the release of the DoD 5000 series of directives and instructions in February 1991. Two notable critics are Lt. General Thomas R. Ferguson and retired Lt. General Glenn A. Kent. General Ferguson served as principal deputy within the Office of the Assistant Secretary of the Air Force for Acquisition and as Commander of the Air Force Materiel Command, Aeronautical Systems Center, the largest of the Air Force acquisition centers. General Kent, a senior analyst with RAND Corporation, at one time directed the Air Force Studies and Analysis Group.

The possibility that the recommendations of the Packard Commission and other defense critics might result in the release of new DoD policies and procedures in the midst of our study was acknowledged at the inception of this effort. Sweeping changes were certain to affect both the "prescribed" and "actual practice" models. In fact, the release of DoDD 5000.1, DoDI

5000.2, and DoDM 5000.2M on 23 February 1991, roughly one month after this effort began, had a major influence on the course of the research.

A primary outcome of the defense acquisition reform initiated by the recommendations of the Packard Commission was the establishment of a set of management offices: an office within the Secretary of Defense, the Office of the Under Secretary of Defense for Acquisition; an office within the Air Force, the Office of the Assistant Secretary of the Air Force (Acquisition) (SAF/AQ); and, more recently, the creation of the Air Force Program Executive Office (AFPEO). SAF/AQ commands the AFPEO that consists of the Assistant Secretary, his principal deputy assistant secretary, and a cadre of seven program executive officers (PEOs). The AFPEO is responsible for shaping and executing weapon system development and production plans.

Total Quality Management and Concurrent Engineering

In addition to the new acquisition directives and reorganizations, several other major initiatives are ongoing within the DoD, such as the commitment to Total Quality Management (TQM). TQM initiatives began primarily in response to international competitive challenges to the American industrial base. The DoD posture on quality issued by the Secretary of Defense, Frank Carlucci, in March 1988, gave top priority to the TQM effort as a vehicle for attaining continuous quality improvement in Air Force operations and as a major strategy to meet the President's productivity objectives under Executive Order 12552.

In an address to the Fourth Quality Improvement Symposium at Wright-Patterson Air Force Base in September of 1989, then Under Secretary of Defense for Acquisition, John A. Betti, stated, "The best way to enhance DoD-industry relations is by improving the quality of defense products and services." At the very heart of this is the DoD TQM initiative.

A critical component of TQM is CE, which recognizes the need for concurrent product and process design. CE, which is synonymous with other terms such as concurrent design, simultaneous engineering, and integrated product development, integrates the product engineering process with the product manufacturing processes and the product support processes, emphasizing efficiency, increased quality, and reduced cost.

The goals of TQM and CE mesh extremely well with a new management approach called Quality Function Deployment (QFD). QFD has been successfully implemented in the Japanese

auto industry, resulting in dramatic reductions in start-up and pre-production costs at Toyota. QFD has been called "simplified systems engineering" and "the voice of the customer." It provides a vehicle to enhance requirements definition and understanding. QFD also provides traceability, and correlates and integrates requirements-associated data currently spread among a multitude of acquisition documents.

The QFD technique encompasses a matrix structure and group analysis approach, thus providing a method to conceptually map the views of multiple functions. The QFD technique also serves as a means for inter-functional planning and communication.

The change in managerial direction and organization spurred the adoption of TQM and QFD techniques, and created a malleable environment ripe for the introduction of decision support technologies to support the weapon systems requirements process.

Summary of Changes to the Requirements Process.

The 23 February 1991 release of the primary DoD guidance on the requirements/ acquisition process includes DoDD 5000.1, DoDI 5000.2, and DoDM 5000.2M. These documents ushered in a new philosophy based on streamlining the acquisition process (a major recommendation of the President's Blue Ribbon Commission, resulting in 61 documents being either canceled and/or consolidated into the three "new" 5000 series documents) and focusing on better requirements determination/definition at the outset of the process. The latter clearly reflecting General Kent's caution that a "requirements" exist for operational capabilities, not for specific hardware and software solutions. In other words, "requirements" are derived from the National Security Objectives and weapon system performance characteristics are merely the means by which the "requirements" are met.

While the changes in the DoD acquisition process are many and a detailed explanation of them all would exceed the scope of this paper, the basic framework of the process, referring to the concept of a graduating sequence of milestone decisions based on the successful completion of each preceding phase, is still intact. Table 1 provides a comparison of the old versus the new program milestones and phases. The primary differences occur at the beginning of the process. The most striking difference is that program initiation, the establishment of a system-specific/programmatic organization (usually termed a System Program Office (SPO)), does not occur in the new scheme until after successful completion of the Concept Exploration and Definition Phase.

Table 1. Comparison of Program Milestone and Phases

OLD	NEW
1. Milestone 0, Program Initiation/Mission Need Decision.	1. Milestone 0, Concept Studies Approval.
2. Phase I, Concept Exploration/Definition.	2. Phase 0, Concept Exploration/ Definition.
3. Milestone I, Concept Demonstration/ Validation Decision.	3. Milestone I, Concept Demonstration Approval. Program Initiation.
4. Phase II, Concept Demonstration/Validation.	4. Phase I, Demonstration & Validation.
5. Milestone II, Full-Scale Development Decision.	5. Milestone II, Development Approval.
6. Phase III, Full-Scale Development/ Manufacturing.	6. Phase II, Engineering and Development.
7. Milestone III, Full-Rate Production and Initial Deployment.	7. Milestone III, Production Approval.
8. Phase IV, Full-Rate Production and Initial Deployment.	8. Phase III, Production and Deployment.
9. Phase V, Operations and Support (overlaps Phase IV).	9. Phase IV, Operations and Support (overlaps Phase III).
10. Milestone IV, Logistics Readiness and Approval.	10. Milestone IV, Major Modification Support Review.
11. Milestone V, Major Upgrade or System Replacement Decision.	11. No Milestone V in new DoDD 5000.2.

Other significant changes occurred in Air Force and milestone review documentation requirements. Table 2 compares the old and new documentation requirements by milestone as well as terminology. Although there may be subtle differences, an obvious correlation exists between the "old" and the "new" documentation (e.g., an "old" Statement of Operational Need (SON) roughly equates to a "new" Mission Need Statement (MNS), an "old" System Operational Requirements Document (SORD) is basically the same as a "new" Operational Requirements Document (ORD), etc.)

Table 2. Comparison of Air Force and Milestone Review Documents
(ACAT I Programs)

OLD	NEW
Milestone 0	
1. SON.	1. MNS.
2. Cooperative Opportunities Document (COD).	2. COD not Required for Milestone 0.
3. Independent Cost Estimate (ICE).	3. ICE not Required for Milestone 0.
Milestone I	
1. SORD.	1. Replaced by ORD.
2. Depot Support Requirements Document.	2. Replaced by ORD.
3. System Concept Paper.	3. Integrated Program Summary (IPS). Annex A: Program Structure. Annex B: Program Life Cycle Cost Estimate Summary. Annex C: Acquisition Strategy Report. Annex D: Risk Assessment. Annex E: Environmental Analysis. Annex F: Affordability Assessment. Annex G: Cooperative Opportunities Document.
4. Baseline Correlation Matrix.	4. Replaced by System Maturity Matrix (SMM).
5. COD.	5. Incorporated into Annex G, IPS.
6. Competitive Prototyping Strategic Waiver.	6. Not Specifically Required, Contained in Acquisition Strategy (Annex C, IPS).
7. System Threat Assessment Report (STAR).	7. STAR.
8. Test & Evaluation Master Plan (TEMP).	8. TEMP.
9. ICE.	9. ICE.
10. Program Baseline.	10. Concept Baseline.
11. Cost and Operational Effectiveness Analysis (COEA).	11. COEA.

Table 2. Comparison of Air Force and Milestone Review Documents (Continued)

OLD	NEW
Milestone I	
	12. Joint Requirements Oversight Council (JROC) Assessment.
	13. Integrated Program Assessment.
	14. Program Life Cycle Cost Estimate .
Milestone II Same as Milestone I except:	
1. Decision Coordinating Paper.	1. Replaced by IPS.
2. Manpower Estimate Report (MER).	2. MER.
3. Acquisition Strategy Report.	3. Incorporated into Annex C, IPS.
4. Program Baseline.	4. Development Baseline.
5. Beyond Low Rate Initial Production (LRIP) Report.	5. Not Required until Milestone III.
Milestone III Same as Milestone II except:	
	1. Beyond LRIP Report.

As previously noted, the most significant changes are those that affect the early stages of requirements definition. The emphasis during this time has shifted from program management/financial issues to user operational/mission requirement issues. The operating command has been given lead responsibility (versus the implementing command) in managing both the conduct of the concept studies and the development of the COEA.

Both concept studies and COEAs are crucial to system requirements definition because they constitute most of the activity during the Concept Exploration and Definition Phase (Phase 0). To facilitate cooperation and teamwork during this critical pre-Milestone I phase, the Air Force established a management body known as the Concept Action Group (CAG). The operating command chairs the CAG and determines CAG membership commensurate with the

needs of the particular acquisition. CAG membership could include Air Staff, implementing and supporting commands, the Air Force Operational Test and Evaluation Center (AFOTEC), and other research, study, and analysis organizations as deemed necessary.

In addition to the CAG, the Air Force established summit requirements and acquisition program reviews. A summit is a senior-level review chaired by the Air Force Chief of Staff (CSAF) for all ongoing major defense acquisition programs. A summit is normally convened once during each phase, prior to milestone decisions, to review and affirm user-stated needs and requirements. The summit also affirms the adequacy of program development efforts to satisfy those needs in a timely, cost-effective manner.

Air Force Restructuring

The total impact of Air Force restructuring is beyond the scope of this paper. The Air Force is undergoing an upheaval unprecedented in its 46 years of existence. In addition to organizational changes, the Air Force will lose about 22 percent of its manpower over the next several years. On 30 September 1990, Air Force strength stood at 532,000. The current authorization bill calls for a drop to 510,000 by the end of fiscal year 1991 (FY91) and to 415,000 by the end of FY95.

Knowledgeable insiders predict that the Air Force will reduce its management structure in the major commands by over 30 percent and that Air Staff will undergo a similar reduction by up to 30 percent. The impact of international events and internal pressures cannot be understated and are bound to result in a fundamental reshaping of the military services.

Restructuring is occurring along two fronts: operations and acquisition/logistics. Within the operations community, TAC, SAC, and the Military Airlift Command (MAC) have been reorganized into two commands. SAC and TAC, with elements of intratheater airlift-type aircraft from MAC have merged to form the Air Combat Command. The new command operates self-sufficient "composite wings" composed of the various types of aircraft needed for foreseeable combat scenarios. Thus, these composite wings contain fighters, bombers, reconnaissance aircraft, tactical airlift, and tanker aircraft. The concept has been described as "One wing, one base, one boss" and presumably "one headquarters." The Air Mobility Command, composed of the remaining MAC functions, provides strategic airlift capability.

In the acquisition/logistics arena, AFLC and AFSC have merged to form the Air Force Materiel Command (AFMC). As with the operating forces, this is a tremendous cultural change for command members. Over the years, the AFLC and AFSC have operated with distinctly different cultures, a natural result of radically different missions, based on the between the acquisition and logistics communities. Recent streamlining of both commands coupled with the quality revolution are the reasons combining now appears feasible.

The concept underlying the new command is Integrated Weapon System Management (IWSM). IWSM recognizes the need for acquisition and logistics systems to work together from the very beginning--a "cradle-to-grave" approach to materiel management. An advantage of this concept is that it presents a single point of contact and a consistent contracting style to both the using command and the defense industry. The intent of the new command is to present one face to industry; IWSM, creates total visibility over a weapon system with one program director supported by labs, acquisition and logistics professionals.

Impact of Restructuring on Project Analysis

Given the degree of organizational turbulence within the Air Force, the impact of these changes on the "requirements" process is impossible to predict precisely. As operating, implementing, and supporting commands merge and missions change, it is difficult to identify the command whose previous methods will prevail or determine whether the new procedures will demand a totally new way of doing things. The latter seems probable; however, time must pass before the new procedures are fully defined. Some of the initial and untested procedures will likely require modification. This hypothesis is supported by the numerous revisions to AFR 57-1. The most recent revision is expected to be a cancellation of the 8 November 1991 version in order to issue policy and a supporting pamphlet.

The products of this research (the models and description of the requirements process) reflect only the directives in force and the subject matter expert (SME) knowledge during the data gathering period of this effort May to November 1991.

Decision Support System for Requirements

The Air Force commitment to the principles of TQM and CE, in an environment of acquisition reform, has spawned additional research to improve the tools and techniques applied within the weapon system acquisition process. Specifically, this research is targeted toward

definition, development, and demonstration of computer-based tools and supporting methodologies that have potential to enhance definition and design efforts early in the weapon system acquisition process.

Our research suggests that such tools can be utilized long before an acquisition contract is awarded. For example, DSS technology could be used by operators to help formulate and prioritize mission requirements within a strategies-to-task framework. Mission requirements, expressed in this manner by the ultimate user, are frequently referred to as the "voice of the customer."

DSS technology can provide sequential support to users: first, by helping a user determine an operational shortfall; next, by assisting in the evaluation of present equipment. If the new requirement cannot be met by anything other than materiel acquisition or modification, the DSS assists in alternative evaluation and selection. In this manner, DSS technology can guide successful management decisions for the design, development, and production of an item. These decisions reflect a solid foundation of mission requirements that are explicitly related to national security objectives. Arbitrary decision-making is replaced by rigorous design analysis. In fact, close and explicit coupling of design requirements to mission requirements reduces the risk of encountering an unplanned design shortfall.

III. TASK CHRONOLOGY

This effort was organized into four logical phases. The phase objectives and methodologies for each are described in the following paragraphs.

Phase I: Preparation

Phase I, Preparation, comprised three objectives: of this phase were to (a) develop, approve, and deliver a detailed research plan (DRP); (b) initiate the literature search, concentrating on the DoD/Air Force guidance/directives, and (c) receive instruction in the IDEF3 process modeling/description capture methodology (IDEF3) and undertake familiarization training on prototype IDEF3 modeling software.

Detailed Research Plan

The DRP reflected the Statement of Work (SOW) tasking to model the requirements process from two perspectives: (a) the process as prescribed by governing directives and (b) the process as actually practiced by field personnel. Modeling was performed from two perspectives because the differences between the two would indicate candidate areas for DSS applications.

Another consideration for the DRP was the SOW requirement to express the findings of this effort via two related IDEF techniques: Activity Modeling (IDEF0) and Process Modeling (IDEF3). This requirement necessitated the construction of eight (two schoolhouse and six real-world) models. Information to construct the models was taken from both the literature search and interviews with acquisition personnel in the various organizations.

IDEF0 activity modeling captures relationships of elements without regard to temporal relationships. IDEF3 process modeling extends the relationships identified through IDEF0 modeling to include temporal relationships. By virtue of this connection, the pair of IDEF techniques fully describes the requirements process.

Since the prescribed process is the same perspective taught by the AFIT School of Systems and Logistics, and since our information collection instrument was to be reviewed by AFIT faculty, this model was identified as the "Schoolhouse" version. For research planning purposes, the "Schoolhouse" model was assumed to include all activities of all Air Force organizations. In IDEF terminology, this model reflects an "objective" viewpoint. Thus, it does not present any particular parochial, command, or organizational slant. Conversely, the second model is the "Practice" version. The perspective of this model considers three viewpoints: SAC, TAC, and the ASD of AFSC).

Assumptions in the DRP include the availability of the Knowledge Based Systems Laboratory (KBSL) prototype IDEF3 software and either an in-house host or the unrestricted use of the Armstrong Laboratory, Logistics Research Division (AL/HRG) computer lab to build the IDEF3 models.

The DRP addresses the collection of adequate source data. A literature search and data collection interviews with acquisition personnel representing various Air Force organizations were the primary data gathering methods used for this effort.

The DRP assumes that the AL/HRG Task Monitor will secure the cooperation of the SMEs' organizations and arrange an interview schedule convenient to the SMEs and consonant with the task schedule.

A recognized element of risk was the immature nature of the IDEF3 methodology and associated IDEF3 prototype software. Consequently, it was determined that the tool should not cost more in man-hours than it is worth. That is, if bugs in the software caused an excessive man-hour drain, an alternate method would be instituted, including hand drawings, if necessary.

The DRP further acknowledges the risk that the release of new DoD policies might dramatically alter the "schoolhouse" version. This risk in conjunction with incremental funding policies, jeopardized the work flow of this effort.

Literature Search

Many relevant documents were identified through the literature search. The timely topics of acquisition reform and requirements improvement were thoroughly addressed by technical journals, monographs, and policy directives. Combined, these sources provided ample data to support the modeling and analysis effort.

The rapid pace of change during the time frame of our effort, made modeling the schoolhouse or prescribed process, as defined in the governing directives, extremely difficult. For example, shortly after task initiation, new DoD policy was issued in the form of DoDD 5000.1 (Defense Acquisition), and its supporting publications, DoDI 5000.2 (Defense Acquisition Management Policies and Procedures) and DoDM 5000.2M (Defense Acquisition Management Documentation and Reports). The new policy was a major revision; it responded to the criticism and recommendations of the Blue Ribbon Commission and incorporated many of Ferguson and Kent's views.

Thus this effort was undertaken at a time when the Air Force, including its major commands, had not yet had sufficient opportunity to publish service-level and command-specific directives. This lack of guidance was detrimental because these directives provide implementing direction for daily business activities.

At the time the DoD 5000 series was released, the primary Air Force directive was AFR 57-1 (Air Force Mission Needs and Operational Requirements Process) dated 7 October 1988. This version was incompatible with the newly specified DoD direction. Subsequently, a draft AFR 57-1 was published on 2 April 1991. Because of the magnitude of the DoD changes and the many comments raised during the coordination cycle, a final version of AFR 57-1 was not published until 8 November 1991. Additionally, an Air Force supplement to DoD 5000.2 was being compiled; this further frustrated any attempts to model business activities.

Additionally, the 800 series of regulations pertaining to Acquisition Management was pronounced "unusable in its present form" by the Pentagon staff officer charged with rewriting and maintaining them. At the time of the interview with this officer, an anticipated publication date for revised Air Force direction was unknown.

The extent to which these changes complicated this effort cannot be understated. In short, what was to be a stable foundation of our analysis (the prescribed requirements procedures) proved to be dynamic. This impaired our ability to model, and also devalued the historical expertise of the SMEs scheduled to be interviewed as sources of valid data. The SMEs were understandably unfamiliar with the business and procedural implications of the new procedures, especially in the area of ACAT I (i.e., systems with research, development, test and evaluation costs exceeding $300 million or with total expenditures expected to exceed $1.8 billion in 1990 constant dollars). Since no acquisitions which meet these criteria were processed during this task many of the revisions had not yet been circulated for comment, it was quite likely that field personnel would be unable to anticipate the effect of new directives.

The new procedures also obscured the subtle differences between the schoolhouse and real-world models because the real-world model lagged the new procedures and had not developed a functional level (i.e., logistics level, operational interpretations, or office-level procedures). This would prove to be a most unfortunate and perhaps overwhelming effect of the dynamic changes to the documented requirements process.

IDEF Instruction

IDEF instruction was an essential element of task preparation because, at the time of task initiation, IDEF3 was an untried, largely undocumented, methodology. IDEF3 was developed by the Texas A&M KBSL while under contract to the government. The only data sources available were three reports published as "beta drafts" under the KBSL contract in April, May,

and July of 1990. Consequently, Systems Exploration Incorporated contracted Knowledge Based Systems, Inc. (KBSI) to conduct an intensive week-long course tailored to specific task requirements and covering the following areas:

- basic IDEF3 methodology;
- application of the methodology to specific task requirements, to include sample models, based on KBSI's preliminary review of the pertinent directives;
- use of the prototype IDEF3 tool to build the models;
- abstraction of IDEF0 models from IDEF3 models to include mapping from one to another as a form of discovery and validation; and
- use of an IDEF0 tool, the AI0 Professional Version.

Phase II: Modeling the "Schoolhouse" Requirements Process

The purpose of Phase II was to produce the schoolhouse models of the requirements process. The approach was to develop both IDEF0 and IDEF3 models using the directives as the primary source material, and to validate and verify the models through interviews with SMEs. To facilitate the interviews, a technique was derived that used the model node tree diagrams to structure the content of the material to be covered, and used a detailed questionnaire to elaborate on each activity, its required inputs, and expected outputs/products.

Pretesting the interview technique was an essential element of data collection. Prior to interviewing SMEs in the various organizations, the models, questionnaires, and interview process were reviewed by laboratory personnel and tested using an AFIT faculty member as a representative SME. Both the laboratory reviewer and the test subject requested some changes but otherwise approved the general data collection approach and material.

This evaluation proved faulty because the reviewers were not representative of the subject pool. The reviewers were more familiar with the topic than were the actual SME; that is, they were either more familiar with the requirements process or with the IDEF presentation technology. Because of the dissimilarity of the reviewers to the SME's, the data collection approach was flawed. Furthermore, SMEs in the field are functionally oriented and possess little familiarity with the overall process. They focus on specific areas of expertise such as intelligence, logistics, or tactics.

Because of the SMEs narrow frame of reference, the questionnaire was too long and somewhat intimidating--even though the SMEs were only asked to comment on the parts of the process with which they were familiar. Care was taken during the interview process to discern between the SMEs knowledge of the process described by directives and regulations, and the process as practiced by field offices. Data pertaining to actual practices was used to construct the practice model.

Phase III: Modeling the "Practice " Requirements Process

The purpose of this phase was to develop the "Practice" models and to further validate the Phase II models. Consequently, this phase was conducted in the same manner as Phase II. The results of the first round of interviews concerning actual practices were incorporated into the models and verified during a second round of interviews. During the second round, the interviewees possessed a broader understanding of the entire process.

Phase IV: Model/Process Analysis, Decision Support System Recommendations and Final Report

The final phase of the task was to analyze the mature models and to assess the viability of using advanced DSS technology at critical junctures of the requirements process.

IV. MODELING METHODS

IDEF Methodology

The analysis conducted under this effort required the construction of IDEF models or descriptions of the "requirements" process. The model begins with the identification of the deficiency and/or opportunity (pre-Milestone 0) and extends through the Milestone III decision to begin the Production and Deployment phase of system acquisition. The DoD publications and AFRs covering the generation, validation, and management of ACAT I weapon system operational requirements comprise a substantial volume of material. The physical acquisition process extends, depending on the complexity and urgency of need, over five to ten years. Therefore, the rationale for modeling was to capture and present the essence of a large amount of information in a more readily absorbable format. Condensing this data to a graphical format facilitates subsequent analysis but requires that the modeler become intimately familiar with the subject matter.

IDEF is an integrated computer-aided manufacturing approach to better communicate and analyze productivity within environments. An IDEF0 model is used to produce a function or activity model that is a structured representation of the major processes within a manufacturing system or environment. The IDEF0 model also presents associated information and objects interrelating those processes. The Automated IDEF0 modeling tool, also called the AI0 Professional Version, was used to facilitate IDEF0 modeling.

IDEF3 is a scenario-driven process flow description capture method. Its goal is to provide a structured method for expressing the domain expert's knowledge about how a particular system or organization works. A scenario may be (a) a sequence of activities that constitute a particular process or event, (b) a set of situations that describe a problem in an organization or system, or (c) a process description in a given setting. IDEF3, unlike IDEF0, provides the capability for capturing temporal precedence and causality relationships between activities. In IDEF3 terminology, these activities are referred to as Units of Behavior (UOBs). The IDEF3 method enables the modeler to display a larger number of objects or concepts associated with a given activity or UOB than the number permitted by IDEF0. The context of the scenario provides a boundary for the IDEF3 description.

The IDEF3 method is applied in the following four steps.

1. Identify the scenarios.
2. Model each scenario by preparing a diagram of the process or event.
3. Prepare an elaboration consisting of facts and constraints in natural language text to support the diagram.
4. Decompose scenarios further and repeat Steps 1 through 3 for each scenario produced.

An attempt was made to use a prototype IDEF3 modeling tool. However, the prototype was under development and unstable, even for the purpose of beta testing. After several unsuccessful attempts, MacDraw and Microsoft Word software were selected for the IDEF3 model. These software packages enabled the production of a written report but did not provide a user-friendly interface for navigating through the model, as is the case with the AI0 tool.

The Integrated Computer-Aided Manufacturing Definition Experience

While IDEF0 has been used extensively by the government and/or contractors for some time, the advent of IDEF3 is relatively recent. The technique was developed by KBSL under Government contract and was delivered to the Government in January of 1991. At the start of this task, there was no commercially available software tool to facilitate IDEF3 modeling. KBSI provided a prototype tool which required a Symbolics list processing machine. Efforts to locate government-furnished equipment (GFE) for the contract period of performance were unsuccessful. Temporary use of GFE for IDEF3 testing revealed that the software was unstable and hindered progress.

A benefit of this effort was the opportunity to compare IDEF0 and IDEF3. Since both methods model identical activities, a comparison could be made with regard to technique utility, descriptive power, and ease of use for both reading/understanding and preparing a model. However, the lack of an IDEF3 software tool of a maturity level comparable to the KBSI AI0 tool prevented a direct comparison of the relative user-friendliness of the techniques for model building.

IDEF3 offers several advantages. First, it is able to relate activities temporally, that is, in the chronological order in which they occur. This is a major improvement over IDEF0, which confuses even experienced IDEF0 users/readers because of the temptation to infer temporal relationships between model entities. Although it may be erroneous to draw temporal conclusions for an IDEF0 diagram, it is natural to assume that the IDEF0 diagram depicts chronological order from top left to bottom right. Users/readers may also be confused by the fact that within a single model, some decompositions accurately reflect temporal relationships by chance while other decompositions do not reflect temporal relationships.

Offsetting this advantage of IDEF3, however, is the fact that when modeling a process as complex, lengthy, and iterative as the "requirements process," the question of which parameter changes first or which document is actually completed first is irrelevant. The precedence of changes to the COEA and the ORD is actually immaterial. It is only essential that documents are changed prior to major reviews (such as the Summit and Defense Acquisition Board (DAB) program/milestone reviews) and that documents are essentially synchronized throughout the requirements process.

Another distinction between IDEF0 and IDEF3 is that IDEF3 does not impose arbitrary limits on the number of functions on a page, nor does it restrict the number of objects attached to any function in any given diagram. Often, in IDEF0, it is necessary to "bundle" concepts into abstract groups in order not to exceed the limit of six concepts per side of an IDEF0 activity, or to group activities into higher-level abstractions so as not to exceed the six activities-per-page limit.

Again, countervailing effects limit this distinction. IDEF0 models require artificial activities because of the restrictions on activities per page. With the IDEF3 technique, some higher-level artificial activities and displayed decompositions could be eliminated; however, these focus attention on "the big picture," which might be lost if one went directly to the lowest level of indenture.

Under this effort, both the directives that produced the "schoolhouse" models and the interviews with the SMEs naturally progressed from a general view/overview to the more particular decomposition of a task. Therefore, it was logical to build the models from a hierarchical perspective; consequently, there is a very close relationship between IDEF0 activities and IDEF3 *functions*.

Notably, the domains of the two models are exactly the same: the activities and responsibilities of various Air Force personnel involved in the identification, validation, and management of weapon system requirements. Since the purpose of IDEF0 and IDEF3 modeling is to capture and/or describe the subject at hand with as much detail and accuracy as the techniques allow, substantial similarities between the IDEF0 and IDEF3 models are expected.

V. ANALYSIS OF MODELS

Assumptions Underlying the Models

The models depict the requirements/acquisition processes as prescribed in the pertinent directives at the time of this research. Additionally, they capture the views of the personnel interviewed. However, the research was predicated on certain basic assumptions which seemed reasonable during task formulation but, in light of the tumultuous changes in both the acquisition processes and the restructuring of the Air Force, require re-examination.

An assumption basic to the task of modeling the schoolhouse process was that there would be current directives from which the information could be extracted. This proved to be an invalid assumption since the primary Air Force directive, AFR 57-1, was not released in final form until after the modeling process was complete. Therefore, the models are in concert with the information available at the time.

Two other rather basic assumptions were also impacted by the events which took place during this research. The first involves the SMEs' level of expertise with regard to the schoolhouse procedures. For example, during this effort three versions of AFR 57-1 were in use. The first was the existing version dated 7 October 1988. This version was clearly incompatible with the new DoD 5000 series publications. During most of the research, the SMEs were in the process of reviewing and commenting on the draft version of the new AFR 57-1. SMEs' comments and questions revealed disagreement with and uncertainty over the new procedures. The final version (dated 8 November 1991) did, in fact, differ from the draft. Therefore, no one at Air Staff; the operating, implementing, and supporting commands; or AFIT could accurately define the "existing" requirements process.

Second, the pending reorganization also impacted SME expertise in regard to actual practice. SAC, for example, was very cooperative, had established a very comprehensive requirements process, and seemed to embrace the new philosophy/procedures. However, SAC personnel expressed the seeming futility of documenting the SAC view, since SAC was about to be deactivated on 1 June 1992. SAC personnel were uncertain if the new Air Combat Command would employ SAC methods, employ TAC methods, or develop a hybrid or new approach.

Scope of the Modeling Effort

The scope of the modeling effort can best be termed ambitious in terms of the period of time modeled, the number of people/organizations involved, and the number of functions defined. The period of time modeled (from identification of the need and/or opportunity through the Milestone III decision to begin production) may be more than 12 years. The number of people involved and/or interviewed includes members of DoD agencies (e.g., the JROC, Cost Analysis Improvement Group, DAB Committees, and the DAB itself), members of two operating command headquarters/staff agencies, and AFIT professors. The number of functions defined range from 120 in the objective view (or schoolhouse model) to 87 in the TAC view, with 93 and 105 in the SAC and ASD models, respectively. Eight models were produced: a process model and an activity model (IDEF3 and IDEF0, respectively) of the schoolhouse

process (a total of two), and process and activity models of the real-world requirements environment from the SAC, TAC, and ASD perspectives (a total of six).

Inherent Limitations of the Modeling Effort

The major limitation of this effort was the relatively small size of the total Air Force requirements community that was used to represent the entire Air Force. For example, research was limited to two operating commands, neither of which is a joint combatant command (such as Air Force Central Command which might have provided more realistic operational or combat-related considerations). Also, only a small percentage of the personnel from each command involved were interviewed. Thus the samplings may not have been truly representative of the commands. In addition, the rank and position of the personnel were limited; consequently, firsthand information was not obtained relative to the more senior level activities (such as Summit reviews, JROC reviews, DAB Documentation and Committee Reviews, and the DAB Milestone Review). The personnel interviewed for this effort could only conjecture as to the nature of these activities.

Differences Between the Schoolhouse and Real-World Process

Given the broad scope of the requirements process and the formality of senior-level review procedures, the requirements process as practiced varies only slightly from the process as prescribed. There are essentially no major differences between the processes. Further, no deviation from the final prescribed documents are permitted. Major commands are still formulating unique implementation procedures that culminate in the final documents. For example, at the time of our interviews, TAC had not yet embraced the need for establishing a CAG (a new requirement contained in the draft AFR 57-1) and had no immediate plans to convene one for their next ACAT I weapon system. However, by the time the next ACAT I weapon system successfully passes the Milestone 0 decision to enter the Concept Exploration phase, TAC will likely have adopted the CAG concept. If the SAC perspective prevails, the process will likely go one step beyond required procedures. For example, SAC has developed a preliminary phase in MNS development: development of a Tentative Need Statement (TNS). The TNS is reviewed by the SAC Requirements Review Group, then forwarded to the implementing and supporting commands as well as Air Staff for their coordination and planning. The TNS becomes a precursor to the MNS.

One difference between the schoolhouse and real-world process lies in how some programs are initiated. The regulations depict a process wherein operating commands identify needs and/or opportunities through a variety of means, largely through the somewhat vague or poorly defined processes known as MAA and MNA. These analyses result in an MNS which is validated by the JROC and, if favorably reviewed by the DAB, passes the first acquisition milestone (Milestone 0) and enters into the Concept Exploration phase to determine the most promising and satisfying solution to the identified deficiency/opportunity. According to research performed by Captain Tom Miller (SAC) and documented in an Air Force survey of operating commands including SAC, TAC, MAC, and Air Training Command (ATC), none of their current or most recent major programs went through an acquisition Concept Exploration phase. Instead, all of these commands' major programs were directed from the top down.

Opportunities for Decision Support System Implementation

Computer usage within the Air Force has changed dramatically over the last several years. Where once there were only a few in an office for people to share, computers are now ubiquitous, with one virtually on every desk at the working level. At the time of this effort, Air Staff was developing a data base to track information on acquisition programs by Program Management Directive number. Likewise, the major commands were tracking the status of their requirements packages through locally developed data bases by TNS or MNS.

Decision Support System Tasks

Certain DSS opportunities were assumed at the start of the interview process. A DSS was expected to facilitate decisions regarding trade-offs within operational and functional areas as well as trade-offs between functional and operational area requirements. Operational mission areas are those defined by the Office of the Under Secretary of Defense for Acquisition, such as Strategic Offense, Strategic Defense, Tactical Air Warfare, etc. (see AFR 57-1, Attachment 10). Functional areas are those which affect the suitability of a system for its intended use such as availability, maintainability, reliability, logistics supportability, etc. A prospective DSS environment might encompass all activities associated with initial requirements determination, requirements analysis, and requirements management.

Interviewees were specifically asked what type of computer support would provide the most benefit. Notably, some functions we might have assumed would be helpful were never

requested. None of the interviewees requested a DSS which would perform a particular type of computation, or apply a technical or quantitative algorithm to a specific problem or trade-off opportunity. There may be reasons for this: prospective users believe the complexity of these types of computations are best left to professional government or contractor operational researcher analysts; or, since weapon system types, current budget considerations, and/or world political situations vary so greatly from major acquisition to major acquisition, similar studies are uncommon and difficult to generalize as subjects for prospective analysis tools. Features unanimously requested, however, were ones that would infuse discipline into the process, integrate the various activities and supporting documentation, and provide generic as well as system-specific training.

Mission Area Assessment and Mission Need Analysis

The first opportunity for employing a DSS presents itself in the areas of MAA and MNA. There is a need for a structured, systematic approach to these activities. This need was documented in the literature and verified in the interviews conducted for this effort. Kent (1989) observed, "Congress is growing increasingly critical of the apparent lack of a logical and persuasive relationship between U.S. military strategies and the defense budgets that it is asked to approve." Research at TAC revealed a TAC study which recommended that action officers be provided with training and tools for performing an MNA and that TAC develop a structured process to integrate MAA and MNA findings into the requirements development process. SAC also expressed a need for improving the process and had initiated a request for a Productivity, Reliability, Availability, and Maintainability project to help them structure their requirements process.

A DSS to support identification of valid needs and/or cost-effective opportunities is clearly indicated by our research and analysis. The DSS envisioned should apply a structured system-engineering-oriented approach to the MAA/MNA or strategy-to-task and task-to-need processes. The DSS could employ a QFD grid or matrix to establish relationships between a hierarchy of National Security Objectives (NSOs) and a corresponding hierarchy of military tasks or operations as a first step in the process. These relationships may range from strongly positive to strongly negative and may depend on the particular concept of operations or relative importance of the NSO in the analysis/decision at hand. Target values for each military task would also be established. Computerization of the process, (i.e., the ability to rapidly create different matrices or insert different values to analyze the robustness of various concepts of operation), will greatly enhance the MAA/MNA phase of the requirements process. The

contribution of the DSS to the analysis of various concepts of operation (and the possible avoidance of a materiel solution) may be of equal or greater value than its contribution to the determination of precise performance operational requirements.

Computerization also facilitates the attachment of attributes or relational entities to each data element in the decision process and thus creates the ability to track, manipulate, analyze, and integrate related decision parameters. Notably, the DSS employed in the MAA/MNA processes supports not only the "traditional" identification of operational deficiencies and technological opportunities, but can also be used effectively to support the development of concepts of operation and mission relationships for directed systems.

Design Specifications

The power of the QFD technique is that it provides a framework for decisions related to subsequent phases of the acquisition, (i.e., the Concept Exploration, and Engineering and Manufacturing Development Phases). The DSS will support definition and refinement of the requirements during the Need Determination (pre-Milestone 0) and Concept Exploration Phases. Toward the end of the Concept Exploration Phase, when the ORD and Concept Baseline are developed and finalized, the set of operational tasks first identified during pre-Milestone 0 activities and refined during Phase 0 will serve as the vertical left-hand axis or starting point for a design-specification QFD grid. The top or horizontal axis of the grid will be the design characteristics associated with each operational requirement. As in the previous matrix, strong, medium, weak, or negative relationships will be established in appropriate grid intersections. In this case, relationships between design characteristics must also be assigned. This is accomplished in the "roof" of the matrix. For example, a design characteristic involving weight may have a positive proportional relationship with an operational requirement for survivability and an inversely proportional relationship with an operational requirement for range. Since the operational requirements are always traceable back to the MAA/MNA phase, design trade-offs can be based largely on the "voice of the customer" rather than the "voice of the engineer." Similarly, design specifications can be compared to manufacturing requirements. When manufacturing decisions are weighed against performance characteristics, the impact of the design decision on mission requirements can quickly be assessed and used as a factor in the decision process. As in the MAA/MNA mode, each matrix element and/or subelement can be embedded with attributes linking it to other decisions, rationale, lessons learned, and documentation.

Integration/Project Management

The acquisition of an ACAT I weapon system is, of necessity, a very complex process requiring input and action from a number of different organizations and creating a myriad of associated documentation. The ACAT I acquisition process spawns numerous studies and analyses, creates innumerable decision/trade-off opportunities, and aggregates lessons learned files while losing or failing to capture decision rationale files/related data. Without exception, interviewee expressed a need for a DSS with strong data tracking, data integration, and project management capabilities.

The DSS data base provides audit trail capability as well as data search and retrieval functions. The need for this capability surfaced in the development and preparation of a recent COEA. One interviewee stated that he was vaguely aware of a previous program-related study that would have been of great value to the COEA effort. However, his numerous other activities and limited time precluded him from expending the necessary time to locate the study. Consequently, the COEA was prepared without benefit of those study results. The final results of the COEA may have been the same; however, considerable unnecessary time, manpower, and money was expended.

In addition, the DSS will have the ability to access, integrate, manipulate, array, and display data in a manner conducive to producing the decisions required of the various factions of the requirements/acquisition community. At any time throughout the acquisition cycle, it will be possible to trace a specific performance, design, or manufacturing data element either back to its origin in the NSOs or laterally to any document which uses it or produces related information. The DSS will also enforce phase and configuration control. Users will be able to access, for analytical purposes, system requirements as they evolve from one phase or document to another. Again, for analytical purposes, any DSS user will be able to review the ORD in its original draft form, as it appeared prior to and after the Summit review, as it appeared before and after DAB documentation and committee reviews, and in its final form as amended by the Milestone review.

Of great concern to the Air Force acquisition personnel that were interviewed was the need to ensure all affected parties were operating with the same data, assumptions, and rationale. Since there are so many different documents prepared by so many different organizations containing either the same data or dependent/derived data, maintaining data consistency/currency is extremely difficult. One of the greatest benefits of the DSS is that it

enforces data consistency. The DSS, by maintaining consistency between documents, contributes to the maintenance of discipline among the various tasks; all participants will know where they are in the acquisition cycle and will be working the appropriate pieces in turn.

The need for data consistency is paramount. For example, the performance requirements specified in the ORD must satisfy the mission need as expressed in the MNS. This set of requirements must also be one alternative evaluated in the COEA. The requirements must also be identical to the performance requirements used to assess the threat against the system in preparation of the STAR. The performance requirements also form the basis for determining both the independent and program life cycle cost estimates. This same set of requirements is also expressed in the Acquisition Program Baseline (APB) for the phase in progress. The APB, in turn, affects and/or is directly affected by the approved acquisition strategy. These same requirements are used as the basis for testing procedures/criteria in the preparation of the TEMP. Progress toward meeting the same system performance requirements is documented in the SMM. Finally, the SMM is used in conjunction with the IPS, Annex D, Risk Assessment, to identify risk and formulate risk reduction plans. The DSS will identify the ramifications which changes to any one of the documents will have on the others and thus facilitate trade-off decisions and/or improve program management. The interviewees noted that changes to the acquisition strategy and/or funding profile of acquisition programs occurred frequently, precipitating many unplanned trade-off decisions. A DSS to support sound decision-making in such an unstable financial environment is urgently needed.

Training

A primary purpose of this study was to identify opportunities wherein a computerized DSS could be used to improve the requirements process with particular emphasis on advancing the CE principles. One method of ensuring that CE principles are factored into requirements/acquisition-related decision-making is to embody them into the algorithms of a DSS of the type described in this report. This type of DSS may be readily adapted to provide an excellent training capability. Its use as a decision/job-aiding device in real time and as a training vehicle for either on-the-job or classroom training would greatly increase the benefits to be derived from the application of CE principles. Without exception, the SMEs who participated in this research expressed the need for a system that would help them in their job and provide training.

The DSS would be capable of providing two types of training. The first is procedural; that is, it would impart knowledge relative to the DoD, Air Force, and Command-specific requirements/acquisition processes, (both the schoolhouse and real-world procedures modeled in this task) with emphasis on CE considerations. The trainer could provide initial requirements/acquisition training to meet the needs of those who are transferred into acquisition positions without benefit of adequate training. The interviewees noted that inadequate training is common. The DSS could also provide refresher/advanced training to experienced users. A procedural training system is particularly apropos at this time because of the magnitude of the recent major changes to the DoD directives/processes and their effect on Air Force and major command implementing directives. These changes have created a universal training requirement; there is now as much need to train seasoned veterans as there is to train newcomers. Compounding the situation is the Air Force reorganization which will affect the operating, implementing, and supporting commands as well as Air Staff. The reorganization creates new commands with combined/modified mission responsibilities, thereby creating an associated need for training. The time, therefore, could not be more opportune to utilize the power of a decision support tool to focus on the new procedures/missions, etc.--especially one that promotes the application of CE principles. In regard to the advancement of CE as a factor in requirements/acquisition decisions, the merger of AFSC and AFLC and the institution of the IWSM concept will also serve as a catalyst to bring about increased CE awareness.

The second type of training is weapon-system-specific and would be of particular value to personnel as they transferred into system-related assignments. Each type of weapon system (e.g., fighter, bomber, missile, trainer, etc.) presents a different set of requirements and/or acquisition problems, and even similar weapon system acquisition programs vary because of differing conditions at the time of the acquisition, (whether political, financial, or technological). The tracking/integrating capabilities of the DSS, therefore, could be used to provide system-specific training in the form of background information, lessons learned, decision rationale files, etc. This capability alleviates the training burden associated with either high turnover (few, if any, personnel remain associated with a particular system throughout its entire procurement cycle) or inadequate initial or specialty training.

Evolutionary Requirements Definition

The purpose of an Evolutionary Requirements Definition (ERD) is to ensure a logical progression from documented operational deficiencies/technological opportunities and new required capabilities (as expressed in broad operational terms in the MNS) to

manufacturing/production quality system specifications (as expressed in contractual terms with the manufacturer) following a successful Milestone III decision. ERD is fully described in Part 4, Section B of the new (23 Feb 91) DoD Instruction 5000.2 and reflects the essence of the revised acquisition procedures. At the heart of the new philosophy is the objective of ERD, which is to progressively refine in greater detail and number at successive milestone decision points the initial broad objectives and minimum acceptable requirements established at Milestone I. ERD is intended to (a) keep all reasonable options open and facilitate cost-schedule-performance trade-offs early in the process and (b) avoid premature commitment to a system-specific solution. (Note that the new procedures do not establish an SPO until after Milestone I vice Milestone 0 under the previous guidance.)

One main benefit of employing a DSS is improved quality of the initial requirements set; however, it is important to recognize that the system requirements developed during the CE phase are still a long way from being contractual product specifications. An indication of the "looseness" of the requirements at this time is given by the AFR 57-1 instructions for preparing the initial COEA. A COEA is a document initially prepared during the Concept Exploration Phase and is required to support a Milestone I decision. Subsequent iterations of the COEA are prepared for a Milestone II decision (and updated for Milestones III and IV, if necessary). AFR 57-1 acknowledges that the limited data available during the Concept Exploration Phase may produce only gross estimates of investment (procurement) costs and that the organizational and operational cost estimates may only be rough estimates. AFR 57-1 further stipulates that cost estimates should be qualified, when necessary, to highlight their weaknesses and any possibilities for gross errors.

The DoDI 5000.2 section on ERDs also places increased emphasis on the involvement of the operating command during the early phases of system acquisition, and their role and responsibilities in developing the ORD. The ORD is the primary requirements document and is the basis for development of the draft system specifications. It also contains the minimum acceptable requirements for key parameters which are incorporated into the APBs (Concept, Development, and Production) and the TEMP as thresholds.

Strategy-to-Task Analysis

The main difference between the "old" (Oct 88) and the "new" (Nov 91) AFR 57-1 is that the former version dealt primarily with documentation and format, (i.e., administrative details), whereas the new version stresses a level of discipline absent in the earlier version.

Because of the criticality of these topics, additional information would be welcome in future editions of the regulation. The strategy-to-task analysis should be the critical initial step in the formulation of new system requirements. Kent further defines the term "requirements", identifying legitimate uses and uses he finds corrupted or obsolete.

For many years, the strategy-to-task analysis, a part of the MAA process, was either improperly done, or not done at all. One interviewee reported that then-current major programs in SAC, TAC, MAC, and ATC were directed programs and were not subjects of classical MAA/MNA/MNS progressions of need analysis. In the course of acquisition, however, these systems would still benefit from a rigorous strategy-to-task analysis to help guide the many trade-off decisions that usually arise for any potential new system. Therefore, the development of a DSS to establish unbreakable links back to the original or underlying "requirements" in the Defense Planning Guidance, would greatly enhance the quality and integrity of the requirements process.

While the strategy-to-task analysis is part of the MAA and may be considered the logical starting point for any given acquisition, it is in fact part of a continuum that includes the MNA and the whole ERD cycle. A strategy-to-task analysis cannot stand by itself; it requires a subsequent task-to-need or MNA to in order to have any relevance. The task-to-need analysis requires a (or multiple) concept of operations to achieve meaningful results. As the requirements evolve through the various stages of the acquisition process, they are altered for a number of reasons, for example, the dynamics of the design/manufacturing interface, changing threat/enemy capability, test results, etc. Each decision resulting in a change to the design which affects performance, regardless of the cause(s), must be evaluated relative to its impact on the underlying NSOs and, therefore, causes the MNA and MAA tasks to be revisited. A DSS can facilitate such an analysis by capturing the relationships between NSOs, military tasks, and design/manufacturing trade-offs for any given concept of operations and keeping these relationships at the forefront of the decision process. Again, this reiterates the primary benefit of a DSS to support the MAA/MNA processes. It never loses sight of or fails to interject the original voice of the customer, that is, the NSOs.

Emphasis on Early Acquisition Cycle Activities

The new AFR 57-1 contains more process guidance and rationale than did the previous edition. Most of these changes affect activities that occur or are initiated early in the acquisition cycle. To complement the emphasis placed on MAA/MNA, the Air Force has assigned

responsibility for developing and preparing the COEA to the operating command (vice the program office/implementing command). This is logical given the overriding objective of defining the "mission" requirements independent of contractual and budgetary constraints imposed by commitment to a system-specific solution too early in the process. A DSS should prove extremely useful in developing operational effectiveness measurement criteria to be used in the COEA. To assist the operating command in managing COEA development, conducting concept studies, and preparing any other pre-Milestone I documents, the Air Force has implemented the CAG approach. The CAG, created along with the publication of the new AFR 57-1, will be chaired by the operating command (usually the Director of Requirements). Membership is determined by the operating command but will usually consist of the lead operating command staff (Deputy Chiefs of Staff for Requirements, Operations, Plans and Programs, Comptroller, Intelligence, Logistics, Communications-Computer Systems, Surgeon General, Personnel, and Security, as appropriate), the implementing and supporting command requirements organizations, the AFOTEC, and other Air Staff and Secretariat offices, as appropriate. The DSS should prove a boon to the CAG concept as well, since it will greatly enhance communication among all members and ensure that all members are current with regard to the latest program/document status.

VI. CONCLUSIONS

Limitations of the Study

The primary limitation of this effort is the scope of the activities modeled and analyzed. The acquisition of an ACAT I weapon system is an extremely complex and lengthy process. To model and analyze every activity from the perspective or viewpoint of the individual involved is beyond the capability of the resources available for this project. Therefore, only the top level of the most important tasks could be accurately described.

The second most important limitation is the composition of the SME interviewee pool. Given the scope, the number of personnel interviewed was relatively small and, in all cases, relatively far removed from the upper management echelon so important to an ACAT I program. For example, much of the models deals with activities chaired by such luminaries as the Assistant Secretary of Defense for Acquisition (the DAB Milestone reviews), the Vice-Chairman of the Joint Chiefs of Staff (JROC reviews), the CSAF (Summits), etc. None of the interviewees were able to provide much first-hand knowledge of these activities. Therefore, most of the information on these important activities was extracted from the directives. In addition,

although the breadth of activities modeled was wide, interviews were relatively brief because interviewees could spare little time away from regular duties.

A third major limitation was imposed by the release of new guidance that substantially changed ACAT I procedures for the acquisition phase of interest in this study: the need determination or pre-Milestone 0 phase. As a result of this release, there were no current Air Force implementing directives. A draft version of AFR 57-1 was in use; however, there were many questions and much uncertainty as to what the final version of the regulation would contain. This rendered the SMEs less than expert in the new acquisition procedures.

Finally, the study took place during a time of unprecedented organizational upheaval. Preparations were being made to consolidate the AFSC (the implementing command of the models) and the AFLC (the supporting command of our models) into the AFMC. The new major command will begin operations 1 July 1992. In addition to the merger, many of the AFSC program management activities, (primarily those dealing with the upper/senior levels of management responsibility such as Air Force representation to the DAB Committee reviews, the JROC reviews, and the DAB Milestone reviews) critical to an ACAT I acquisition had already transferred to the Office of the Assistant Secretary of the Air Force for Acquisition and his body of PEOs. Consequently, interviewees were even further removed from the workings of top-level program management. Furthermore, the operating commands (SAC and TAC) were also in the throes of reorganization/consolidation into the Air Combat Command (which becomes effective 1 June 1992). Reorganizations of this magnitude caused most SMEs to be unsure of the exact procedures the new commands would adopt.

General Findings

The objectives of the task--to gain a deep thorough understanding of and describe the environment of the potential requirements-process DSS user and to identify opportunities for which a DSS could be beneficially employed were accomplished. A DSS can fill a void in the current requirements process by providing a means to enhance the quality of strategy-to-task analyses which are part of the MAA process, by similarly enhancing the task-to-need or MNA process, and by establishing links between the weapon system requirements as they evolve during the course of the acquisition process and the basic national security requirements. Since one of the greatest opportunities for DSS employment lies in the formulation of traceable relationships between NSOs and design considerations, its use should not be limited to pre-Milestone 0 activities. These relationships can be used to guide decisions throughout the full

range of acquisition phases/milestone decisions. Therefore, the DSS must be compatible with the Program Manager's Support Systems (PMSS), the Acquisition Program Tracking System (APTS), and other requirements, acquisition, program tracking, and management systems.

The new directives (in particular AFR 57-1) contain much more rationale and process information than did their predecessors; however, the DoD and Air Force acquisition processes are still heavily laden with documentation requirements. One of the more important pre-Milestone review activities is the DAB Committee documentation review. Thus, it follows that one of the major benefits of the DSS will be its ability to integrate data among the various documents. It is critical that all offices with primary responsibilities for the various documents operate with current, complete, and accurate information. It is also imperative that the decision-maker consider the effect the decision will have on the myriad of other documents/acquisition processes which may be affected. The ability to integrate and provide this data was one of the SMEs' most often requested features in a requirements process DSS.

The SMEs believe that a DSS which could provide both process and system-specific training would be of tremendous value in enhancing the requirements process. This was particularly true of personnel who were newly assigned to a requirements/acquisition position from another career field, as is often the case with aircrew/rated personnel. These people are highly skilled and possess exceptional practical knowledge as to what the system requirements should be, but they often have no working knowledge of the requirements/acquisition process. A DSS which could impart the required process information in addition to bringing the newly assigned person up-to-speed on a particular system in acquisition would pay for itself quickly. Use of the DSS would standardize the process across all organizations. In light of the organizational changes currently taking place in the Air Force, a standardized training approach seems particularly attractive.

One task of this study was to identify the differences between the requirements process as prescribed by directive and taught at AFIT (the schoolhouse process) and the real-world process. Although the schoolhouse process changed during the course of the study, the two processes (i.e., schoolhouse and real-world) are not now (nor were they ever) very different. The only differences recorded in the models were the relatively minor SAC variation of producing a TNS prior to a more formal and "required" MNS, and the reluctance of TAC to convene a CAG should the need arise (however, this may change). It will take some time before all the nuances of the new procedures are fully understood and incorporated into actual practice. Other differences such as the TAC MAA (labeled "Review AF Planning Guidance" in the model) and

Preliminary Integrated Manpower Personnel and Consolidated Training Program Plan activities (incorporated in the TAC ORD preparation activities) can be primarily attributed to the lack of definitive Air Force guidance (which, in turn, is attributable to the revised DoD policies) and to the turmoil created by the complete reorganization/dissolution of the major operating, implementing, and supporting commands (i.e., SAC, TAC, MAC, AFLC, and AFSC).

Future Directions for Similar Work

Future research should be directed toward developing methods to adapt the QFD matrix format to a more user-friendly personal computer screen-type format. The result might resemble a spreadsheet; however, each cell would be linked via attributes to a relational data base. IDEF1x is recommended to develop the "to be" relational data base system.

Furthermore, the development of a prototype DSS for more immediate use on ACAT III/IV acquisitions is recommended. This approach would facilitate access to more "users" of the system at relatively higher levels of authority within the program than is available in ACAT I/II programs. Also, the experience gained could be directly applied to major (ACAT I/II) systems in follow-on efforts. Another approach would be to develop the DSS to satisfy the needs of major acquisition subsystems.

Additional research is needed to examine existing commercial off-the-shelf software applications which could be readily adapted to the DSS. Some of these applications may be sufficiently sophisticated to meet the needs of ACAT III/IV systems. For example, during this limited research effort, existing software packages that facilitate automated document generation (such as system specifications, work breakdown structures, functional flow diagrams, requests for proposals, SOWs, etc.) were identified. Future research should also examine relevant government software applications, including those that are weapon system specific but could be generalized.

REFERENCES

Kent, Glenn A. (1989). *A framework for defense planning*. Santa Monica: The RAND Corporation.

ACRONYMS

AI0	AI0 Professional Version Software
ACAT	Acquisition Category
AFIT	Air Force Institute of Technology
AFLC	Air Force Logistics Command
AFMC	Air Force Materiel Command
AFOTEC	Air Force Operational Test and Evaluation Center
AFPEO	Air Force Program Executive Office
AFR	Air Force Regulation
AFSC	Air Force Systems Command
AL/HRG	Armstrong Laboratory, Logistics Research Division
APB	Acquisition Program Baseline
APTS	Acquisition Program Tracking System
ASD	Aeronautical Systems Division of Air Force Systems Command
ATC	Air Training Command
CAG	Concept Action Group
CE	Concurrent Engineering
COD	Cooperative Opportunities Document
COEA	Cost and Operational Effectiveness Analysis
CSAF	Air Force Chief of Staff
DAB	Defense Acquisition Board
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DoDM	Department of Defense Manual
DRP	Detailed Research Plan
DSS	Decision Support System
ERD	Evolutionary Requirements Definition
FY	Fiscal Year
GFE	Government Furnished Equipment
HQ	Headquarters
ICE	Independent Cost Estimate
IDEF	Integrated Computer-Aided Manufacturing Definition
IDEF0	Integrated Computer-Aided Manufacturing Definition, Activity Modeling
IDEF3	Integrated Computer-Aided Manufacturing Definition, Process Modeling

ACRONYMS (Continued)

IPS	Integrated Program Summary
IWSM	Integrated Weapon Systems Management
JROC	Joint Requirements Oversight Council
KBSI	Knowledge Based Systems Incorporated
KBSL	Knowledge Based Systems Laboratory
LRIP	Low Rate Initial Production
MAA	Mission Area Assessment
MAC	Military Airlift Command
MER	Manpower Estimate Report
MNA	Mission Need Analysis
MNS	Mission Need Statement
NSO	National Security Objective
ORD	Operational Requirements Document
PEO	Program Executive Officer
PMSS	Program Manager's Support System
QFD	Quality Function Deployment
SAC	Strategic Air Command
SAF/AQ	Assistant Secretary of the Air Force (Acquisition)
SAF/AQX	Deputy Assistant Secretary of the Air Force (Management Policy and Program Integration)
SME	Subject Matter Expert
SMM	System Maturity Matrix
SON	Statement of Operational Need
SORD	System Operational Requirements Document
SOW	Statement of Work
SPO	System Program Office
STAR	System Threat Assessment Report
TAC	Tactical Air Command
TEMP	Test and Evaluation Master Plan
TNS	Tentative Need Statement
TQM	Total Quality Management
UOB	Unit Of Behavior

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U.S.G.P.O.:1993-550-057/81053